欢迎与会的各位专家！
Using S-parameters for behavioral interconnect modeling

Asian IBIS Summit

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Agenda

- Using S-parameters for high-Speed digital design
- Describing passive interconnects in ICM
- ICM&IBIS
- A solution for package modeling using S-parameters
- Summary
Using S-parameters for high-Speed Digital Design

- The signal integrity simulation of high-speed digital design requires that the interconnect modeling must be valid over a wide bandwidth.
- S-parameters can be generated by 3D EM field solver or by VNA and TDR/TDT measurements.
- S-parameters can be used to generate distributed models for transmission line and vias.
- S-parameters model can be easily correlated with VNA measurements.
- Circuit simulators can run both S-parameters and RLGC models together in time-domain.
S-parameters Extraction and Correlation

- TDR&TDT Measurements
- FFT Transform
- S-Parameters
- Time-Domain Simulation
- EM field Solver
- VNA Measurements
- Model Correlation

Top
Bottom
### Measurement and 3D EM Solver Modeling

#### Measurement setup

#### 3D EM Solver Modeling

### S-Parameter touchstone file

```
! FILE NAME
! DATE 10/20/05   22:27
! CORRECTED DATA
# GHz    S       MA      R    50.00
0.01000000  3.217487E-02  25.539  1.433922E-02  73.163  7.022051E-04 -164.797  9.721752E-01  -14.501
  1.437112E-02   73.522  8.309287E-02  25.536  9.721752E-01  -14.501  1.433922E-02   73.163
0.019987500  4.338055E-02  24.741  2.753260E-02  60.190  2.753260E-02  60.190

0.029975000  5.279364E-02   19.352  4.905304E-02  34.608  4.905304E-02  34.608
```

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**2006-10-27**  
Using S-parameters for behavioral interconnect modeling
Lab Correlation for S-parameters

S21 data comparison between VNA measurement and Simulation
Simulation using S-parameters and SPICE models

1. Simulation using S-parameters extracted by EM field solver
2. Simulation using RLGC models
3. Correlate with laboratory measurements

Measurement versus Simulation
Lab Correlation for S-parameters and SPICE models

Blue curve: S-parameters
Red curve: SPICE models
Green curve: VNA measurement

Time [ns]

0 1 2 3 4 5 6 7 8 9 10 11

V [V]

HSpice: v_out_spice_siwave
HSpice: v_out_VNA
HSpice: v_out_S_siwave
ICM&IBIS

- IBIS Interconnect Modeling Specification (ICM) permits model authors to describe passive interconnects in a tool-neutral, behavioral, human-readable way similar to IBIS.
- ICM supports S-parameter data.
- ICM supports RLGC frequency-dependent matrices.
- ICM does not include connections between IBIS [Model], IBIS [Pin] and ICM ports today.
Describing passive interconnects in ICM

[Begin_ICM_Section] S_para_example
[Derivation Method] Lumped
[ICM S-parameter]
File_name test.snp
Port_assignment

<table>
<thead>
<tr>
<th>Port</th>
<th>Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
</tr>
<tr>
<td>2</td>
<td>B1</td>
</tr>
<tr>
<td>3</td>
<td>A2</td>
</tr>
<tr>
<td>4</td>
<td>B2</td>
</tr>
<tr>
<td>5</td>
<td>A3</td>
</tr>
<tr>
<td>6</td>
<td>B3</td>
</tr>
<tr>
<td>7</td>
<td>A4</td>
</tr>
<tr>
<td>8</td>
<td>B4</td>
</tr>
</tbody>
</table>

[End ICM Section] S_para_example
How do we link ICM to IBIS?
[ External Circuit ] in IBIS ver4.2

- Accepting SPICE, VHDL-AMS, Verilog-AMS, VHDL-A(MS) or Verilog-A(AMS) as arguments.

A proposal for IBIS package modeling using S-parameters

New syntax required for arbitrary ports

Language → Touchstone?
Linking ICM to IBIS

[Node Declarations]
|Die pads or pin names
A1, A2, A3, A4
pad1, pad2, pad3, pad4
[End Node Declarations]

[ICM Pin Map] sample_int
Pin_order Row_ordered
Num_of_columns = 4
Num_of_rows = 1
Pin_list
|Pin Name
pad1 D1
pad2 D2
pad3 D3
pad4 D4

To Buffer

ICM

IBIS
How do we use S-parameters for package modeling now?
Package modeling using S-parameters

- Many EDA tools support S-parameter simulation.
- Using subcircuits to describe S-parameter model.
- Replacing IBIS [Package Model] by S-parameter model.

![Diagram showing IBIS Buffer and Package model with actual pins connected through S parameters.]
A solution for package modeling using S-parameters

S-parameters can be added to Cadence DML file.

S-parameter model:

```
("../../../Pkg_models/s_para_pkg.dml"
(PackagedDevice
 (s_para_pkg
  (ESpice ".subckt s_para_pkg 1 2 3 4
 Xs_para_pkg_4Port 1 3 2 4

.subckt s_para_pkg_4Port_Data 1 2 3 4
 S1 1 2 3 4 algorithm=default
 DATAPoints SPARAM
 R=50.000000
 DATAUNIT=HZ
 FREQUENCY=0.000000e+000
 .
 . END SPARAM
.ends s_para_pkg_4Port_Data

.ends s_para_pkg_4Port"
  (PinConnections
 .
   (NumberOfPorts 4 )
   (SubType SPARAM ) )
   (LibraryVersion 136.2 )
  )
)
```
A solution for package modeling using S-parameters

- IBIS IO buffer modeling
- S-parameter package models of transceiver
- Connecting buffer models to package models in topology.

TX_device

![Diagram of TX_device](image)

RX_device

![Diagram of RX_device](image)
Summary

- **S parameter features:**
  - Behavioral modeling method compatible with IBIS style.
  - Much shorter simulation time compared with RLC connector models.

- **Benefit IBIS ICM with S parameter:**
  - "One model, one platform, one simulator" for both active and passive components.
  - Pave the way for behavioral, yet accurate enough IBIS simulation for very high speed circuit well beyond gigahertz.
References

- Michael Mirmak, "IBIS & ICM Interfacing: A New Proposal".
- IBIS Interconnect Modeling Specification (ICM) Version 1.0 (Sept. 12, 2003)
- I/O Buffer Information Specification (IBIS) Version 4.2 (June 2, 2006)
Global Connections Universal Solutions

Thank You